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SEMI-CENTENNIAL, ITHACA, JUNE, 1936

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THE SEMI-CENTENNIAL

This important event in the history of our great society and of the promotion of research in the United States and Canada is scheduled to take place in Ithaca, New York, June 19 and 20. The American Association for the advancement of science is generously cooperating with our committee of arrangements and has made our semi-centennial program a part of the plan for the summer meeting of the Association which will convene in Rochester during that week.

The Sigma Xi program will be a brilliant one. Dr. Karl T. Compton, President of the Massachusetts Institute of Technology, will deliver an address on "The Service of Sigma Xi in the Universities of the Future." Doctor Compton's utterances carry great weight in all fields of scientific endeavor, in the sphere of administration of educational organizations, and on questions of the relations of governmental subsidy of scientific research. His address will definitely emphasize the important part that Sigma Xi may play in the forward-moving educational institution during the next quarter century.

Dr. Willis Rodney Whitney, until recently director of the famous research laboratory of the General Electric Company and now Vice-President of the company in charge of research, will speak on "The Accomplishments and the Future of the Physical Sciences." While Doctor Whitney has been one of the prominent scientists of this country in his able pursuit of research in applied science, he has never lost sight of the enormous

value of investigations in pure science and because of his enthusiastic interest and extraordinary ability the General Electric Company has generously supported research in scientific theory.

Prof. Frank R. Lillie, the widely-known professor of embryology at the University of Chicago will represent the biological sciences on the semi-centennial program, speaking on "The Accomplishments and the Future of the Biological Sciences."

The Trustees of Cornell University have voted to erect a bronze tablet on the campus commemorating the Semi-centennial of Sigma Xi and have engaged an architect to design the tablet and an art firm to make it.

There are to be two Semi-Centennial Research Prizes of $1,000 each—one for a worker in the physical sciences and one for a worker in the biological sciences. Chapters and Clubs have been requested to name one candidate for each of these awards. The nominations are to be made to the office of the national secretary before February, 1936, and the awards will be decided by a committee especially appointed by the national president as follows:

Prof. Harold C. Urey, Columbia University, chairman.
Dean Joseph W. Barker, Columbia University.
Prof. George A. Baitsell, Yale University.
Dr. William B. Castle, Harvard Medical School.
Prof. Edward U. Condon, Princeton University.

Since last April work has been in progress in the office of the national secretary on the proposed Semi-centennial History and Record to be issued as part of our celebration. We have on our records upwards of 27,000 names of Sigma Xi members and associates. The labor of bringing the addresses up to date is prodigious with our limited staff of office assistance. Alumni Recorders of the institutions where there are chapters and clubs are cooperating with us to the extent of their information. At the time of going to press with this issue, the national secretary has received corrected address lists from forty of the sixty-six chapters, and the permanent records of these chapters on file in the national executive office have been brought up to date. The

alphabetical and geographical files of members and associates of nine of these chapters are now complete. Twenty-six chapters have not yet submitted corrected address lists.

The program of the celebration:

Friday Afternoon, June 19

a. Greetings from Cornell University.

b. Response from the President of Sigma Xi.

c. A brief history of Sigma Xi.

d. Address: The Service of Sigma Xi in the Universities of the Future. Dr. Karl T. Compton, President of the Massachusetts Institute of Technology.

Friday Evening, June 19

a. The Semi-centennial Dinner.

b. Address: Scientific Research and the Social Order, Present and Future.

Saturday Morning, June 20

a. Unveiling the Semi-centennial Memorial Tablet.

b. Address: Accomplishments and the Future of the Physical Sciences. Dr. Willis R. Whitney, Vice-President of the General Electric Company, in charge of Research.

c. Address: Accomplishments and the Future of the Biological Sciences. Prof. Frank R. Lillie, University of Chicago.

THE THIRTY-SIXTH CONVENTION

The thirty-sixth Annual Convention of the Society will be held in St. Louis Tuesday, December 31. The executive officers will meet at two o'clock in the afternoon of that day for the second meeting of 1935. The business session will convene at four o'clock, and the fourteenth annual lecture under the auspices of the A. A. A. S. and Sigma Xi will be given in the evening by Mr. John Bellamy Taylor of the Research Laboratory of the General Electric Company.

No one knows better than the National Officers of the Society that it may be difficult for chapters and clubs to send delegates both to the Annual Convention at St. Louis and to the Semi-centennial at Ithaca. Both events are of great importance. It is earnestly hoped that all chapters and clubs will be represented at Ithaca by a large delegation. There can be only one Semi-centennial in the history of the Society, and the arrangements for that important event present such a brilliant program that all who are present are bound to receive profound impressions about the Society and its purpose—namely, the promotion of research.

On the other hand, business of considerable importance is to be presented to the Convention. There will be a number of formal printed petitions for charters, upon which the Convention will be asked by the Executive Committee to take action. Copies of these petitions will be distributed to the chapters well in advance of the Convention in order that chapters may have ample time to acquaint themselves with the scientific conditions at the institutions involved. Officers of the Society are to be chosen for the ensuing biennium, as well as members of the Executive Committee and the Alumni Committee for the succeeding five-year period.

The nominating committee appointed by President Parker to present candidates for these offices is as follows: Prof. Joseph K. Roberts, University of Virginia, chairman; Prof. B. F. Kingsbury of Cornell University; and Prof. Walter L. Upson of Washington University. Chapters may make suggestions direct to the members of the committee, or through the office of the National Secretary. All suggestions will be given careful study by the committee.

It is therefore hoped that chapters and clubs will make an effort to send delegates to the St. Louis meeting. Chapters are entitled to a delegation of not more than three members. Clubs are entitled to one delegate who has the privilege of the floor. In case chapters or clubs are unable to send its own members, they may appoint members of any other chapter as representatives.

LASTING VALUES IN GOVERNMENT

A. A. Berle, Jr.
Columbia University Law School

Recurrently in the history of the world a whole civilization knowingly approaches a visible climax. This differs materially from the periodic crises arising out of problems of economics. The fact is foreshadowed by two conditions both observable to intelligent students of their own times.

The one is a decadence of civilization; but the word decadence as here used is defined by Miss Beatrice Bishop as being a condition in which civilization no longer believes in the rules and morals which it professes. The other is the impact of a new ideology which by hypothesis assumes to discard any of the values which civilization has regarded as supreme.

I submit to you that both of these conditions are visible today. Western civilization in the resurgent form which it assumed after the Dark Ages has been built upon a spiritual thesis: a thesis which assumed that civilization was not and never could be self-contained. No man, no group of men, no nation, no league of nations could determine their conduct or take their decision except as they referred to the text of some higher and greater law. They might fail in realizing that law; or they might sin by failing to observe it; but at no time was it to be assumed that within the limits of any form or of any human brain could civilization attain itself. Even if it were necessary to use the pitiful expedient of almost deifying a king, as did France in the days of Louis XIV, the emphasis was invariably upon a responsibility to some ethical law represented in turn by some organization of the group of instincts of men which invariably seek after a divine order of things. When the first great breach in the constant fabric was made by Napoleon Bonaparte he is said to have observed in one of his rare moments of clarity that he feared the result of the thing his time and his forces had wrought. The old institution of feudalism had been loyal at least to an idea of chivalry; the old institution of royalty to a theory of divine origin; the old institution of the Church to the frank acceptance of the Lord Almighty. But this incoming civilization, based partly on force and partly on money, seemed to him self-contained and therefore, if you will pardon the paradox, incomplete. And he feared to look a century ahead wondering lest the old protections had gone with the old limits.

That there has been a widespread skepticism of the rules of ethics on which our civilization has been based, only the blind would deny. We have, if you please, run after false Gods; the futures of self-control, and of industry and of fulfillment of mutual obligations have seemed pale when set against a system which frequently rewarded the violators of those responsibilities and left little people who would observe them as helpless wrecks in an economic wash.

The conflict of ideology is plain. In western civilization which is to say in practice Europe and America, we are seeing the rising tide of a philosophy almost directly antithetic to our own. Probably Professor Harry Elmer Barnes

is right in tracing the line at least as far back as Nietsche and to the doctrine that the superman showed himself by his strength and proved himself by breaking all ethical barriers; that acceptance of traditional human obligations was a sign of weakness. Whether the source was Nietsche or whether it comes from an older source the result is plain enough. The larger half of Europe from the Ural Mountains to the Rhine openly professes and violently practices a philosophy which frankly submerges individual rights and individual obligations in a theory of mastership; and the doctrine is the same whether it be the mastership of a proletarian class or the mastership of a vast group. The tremors which periodically shake the government of France indicate that this philosophy has made no boundary as yet; England and ourselves alone among the great powers cling tenaciously to an older form.

The antithesis is clear. On the one hand is faith in obligations universally accepted and voluntarily even gladly assumed by every member of the state towards the state and towards each other, vesting in government the power and authority to see that these obligations thus freely assumed are carried out. On the other, trust is reposed in a class or group to enforce rules in order to make society a workable machine, based on the primary conception that the power belongs to him who can take it and that strength makes its own laws. Gone is the idea of individual justice, or the voluntary quality of obligation, or the responsibility to any ethical law; and stress is accordingly laid on the quite earthly results of glory and material welfare.

You will readily realize that this is, in modern dress, little more than one of those ancient crises which we all of us have studied as being in the history of the Christian Church. The contest between a world ordered on the basis of human brotherhood, accepting obligations by reason of a universal and tremendously dynamic law of love, and a world based on a Diabolonian philosophy is old in our annals. Debates of today have somehow an ancient echo; they suggest, for example, the tremendous controversy over Manichaeanism; except that we have no St. Thomas Aquinas to set boldly forth the Deist ideal. Perhaps we will be well advised to realize the proportions of that contest. For, as it seems to me, upon the outcome of this contest is likely to turn the fate of a considerable part of the world for the next few centuries.

In dealing with high government, we are well advised to examine the forces which are at work. They are three. The first group are technical and have to do with the decisions of the moment. Politicians and business men use these forces daily. The second group operates at longer range. These are the intellectual forces and the masters of them are the scholars, the teachers and the scientists. No politician and no business man can do very much more than translate into action the commonly accepted and tested ideas of the day. These ideas are those which the intellects of a decade or even a generation ago have forged out, have translated as best they could, and which have filtered through students and resulted in the stream of ideas on which estate is based. A government which endeavored to manufacture ideas or even to use ideas before they were commonly accepted would find little success. In the dark days of 1933 when an emergency group was endeavoring to wrestle with the problems of economic

breakdown, there were many who suggested that the time had come for a more or less complete change in the methods by which the business and government of the country were carried on. Mr. Roosevelt wisely, as it seemed to me, determined against this both because he had no mandate to revolutionize American economics, but still more because whatever change might be made in form at that time, little would be accomplished if the ideas of the people remained the same. You would merely have the same result dressed in a different garb. It is merely one of the usual ironies of history that today some groups attack him for having saved an order of things which they were unable to salvage, and the attack is based, God save the mark, not on his having attempted too little, but on his having attempted too much.

The third and greatest group of forces is the longest range group of all. They are ethical and spiritual. Without them neither the short range effectiveness of action nor the longer range effectiveness of thought can mean very much. Even the student in his chamber has to make some choice of the things he will study, of the hypothesis which he thinks needs re-examination. He must do this on some theory of relative usefulness—else research would regard with equal value a count of paving stones in the City of New York and a study for the prevention of tuberculosis. My point is that the fundamental spiritual values which dominate the conduct of the time determine and build a major part in the creation of the intellectual forces; these in their turn condition the short range action.

But the spiritual forces do considerably more than this. There must not only be the ability to think, but an impelling motive to think. There must be not only a reason to act, but an impelling motive to act well. The spiritual like the intellectual force is never spent. If it has behind it that driving quality which we have been taught to know as faith, it supplies for the civilization it builds a continuous ever-beating heart pumping life-blood into thought and decision alike.

I make no apology for thus having discussed perhaps over long the philosophy familiar to you all because as it seems to me the driving necessities of the situation lead us at long last to use our philosophy and our faith and to use them now and with all the strength we can muster. If my estimate of the situation is accurate, the country at the moment needs a few practicing saints far more than it needs the most expert of practicing politicians. This is not said in any casual spirit of lip service. I mean exactly what I say; for without some rejuvenation of this spiritual heart I do not see that we can enter the next two decades with the slightest certainty that the civilization we hold dear can possibly succeed. If you will bear with me, I would like to lay out exactly why I think this is so.

We have at the moment an economics which has outlived its form and its thought. If you please, it has run loose and wild; and its control is not even vaguely in sight. We relied for a century on an economics of balance, based on the theory that individuals could be led by a profit motive to serve society; and that matters were so adjusted that when they had ceased to be serviceable their profits would cease and they would automatically find a place somewhere else. Competition, comparative efficiency, would mean that no single unit would get out of hand; and the occasional casualties of the continued economic conflict

could be taken care of by the humane instincts of men acting cooperatively for the relief of distress.

This was the philosophy worked out in the eighteenth century. Within limits it served fairly well. But the organization of forces: the rise of the great machines, of the great corporations, and of a credit mechanism so confused as to be out of control and so blind that literally no one now understands it, has changed that situation in the short space of a generation and a half. We no longer can say that there is a balance of forces, we know only too well that there is not. We no longer can say that the combined forces, aided somewhat by normal kindly instincts, take care of a population. We have seen in the last few years nearly a quarter of the vast population of the United States shaken loose from its moorings, and thrown, a mighty mass of débris, at the feet of the State itself. And we have seen this happen apparently without reference to whether any member of society kept his obligations to himself, to his family, to his neighbor and to his God, or whether he had violated every law human or divine.

On the other hand we have rising an opposing theory of government; which begins by assuming that no obligation will be assumed by any group except under compulsion; and that using hatred as a weapon, destruction of money groups and classes may ultimately result in vast power in a dictatorship, proletarian or personal, which will enforce the obligations as to the system which seems best. Robert Briffault in a recent book insists that no permanent correction of the distorted mechanism we now have can be achieved by men of kindly instincts or who are actuated by good-will. Only a class so depressed that it is inspired by hatred, meanness, and desire for revenge can be galvanized (as it seems to him) into action sufficiently drastic or sufficiently sweeping to achieve a result. And there you have in a terse illustration the kind of thing with which we now must contend. On the one hand it is conceded that we have a civilization requiring a new self-control and the assumption of responsibilities new to all of us. On the other the insistence that no civilization will undertake these responsibilities unless it is goaded by hate and entrusted to men dominated with a combined desire for revenge and power.

All of us are aware of the taunt usually thrown at men who believe in the Christian philosophy. It is, that that doctrine merely serves to allure unhappy men who ought to be afire with a sense of their own wrong; that it is an anodyne administered by a self-seeking class to allay discontent in men who have every right to be discontented. There is, I think, no answer to this taunt except to meet the challenge.

We have in our own philosophy of life a doctrine infinitely stronger than that of hatred and infinitely more applicable to the present situation than that either of a Caesarian fascism or a proletarian communism. By hypothesis we acknowledge the brotherhood of man—an infinitely more powerful doctrine than ever is made by an insistence on the solidarity of any class.

We have likewise as a cardinal tenet the belief that the acceptance of each other's burdens is a part of the fundamental law of life. Out of this should follow an ordered civilization and a logic of discipline which need no help from hatred; and no compulsion from force or fraud. The thing that is wanting is

faith in our process; a faith which will inspire the intellectual to examine his thesis and the statesman and the business man so to act that the best thought looking towards the achievement of this universal civilization is fairly carried out. It is for that reason that I am asking tonight, naïvely but in all sincerity, for a practicing saint—a man or group of men who are prepared once more to infuse into this mass of tangled affairs the faith which makes having inherited once more an effective note.

My economics may teach me that a corporation without control is rather more dangerous than a locomotive off the track; and my technique may teach me to frame a federal incorporation law which can control the corporation; but only reliance on the ethical qualities of men can make possible a control which will not be abused or a scheme of things which will not be violated. A government can impose mechanisms; but only a general agreement that they are for the common good can lead to an acceptance wide enough to make them worth doing. As a student I can say with perfect certainty that a capitalist civilization cannot continue unless every capitalist asks himself whether he renders an adequate service for every dollar he takes in.

But only an acceptance of the obligation to render service for value, otherwise to take no part of that value, will make the idea valid. Shot through the entire problem is the constant realization that neither strength nor action nor thought nor the power of finance nor the mechanisms of society can do anything save as they conform to certain ethical standards of obligation; and as they confidently accept a recognition of those obligations in others.

Compared to this, the submergence of the individual in a communist state or at the behest of a nazi government is almost child-like. In the tremendous confines of the doctrine of sacrifice in the common good there is a force only too weakly imitated by the philosophy which now rises to insist that individual fulfillment ceases to exist and that man's chief need is to glorify the leader or a state. The doctrine of personal discipline and of self-abnegation is no stranger to Christian thought. Almost it may be said to be the foundation of Christian thought. The difference lies in the fact that out of that self-abnegation men could find their souls and themselves.

It would seem then that the defects in our work for the past decade have been that we failed to emphasize the doctrines of self-abnegation and of self-sacrifice as a necessary concomitant of life; or perhaps that we allowed those doctrines full force when dealing with other people, and failed to apply them to ourselves. But I see no reason why we should not say to princes of property or to the strong classes that they have an obligation in a Christian State which involves many of the duties which might be exacted of them by a dictatorship, the difference being that in the one case it is a free gift to the universal service, whereas in the other it is a tribute wrung by force.

The lasting values of government have been those common services performed in ever-widening measure by the State to the body politic. This is almost an unbroken history. Commencing with the sovereign gift of peace and order, continuing with the justice of certain material services needed in the general welfare, now to the satisfaction in some measure of esthetic needs, governments

have carried forward in one form or another the heritage of civilization. Faced with a crisis which requires a still greater application of the common mind to the common welfare, we once more refer to the underlying spiritual power. When the common welfare is in danger or possibly threatened, when economics ceases to meet the underlying demand for justice which will work itself out in the lapse of at least the overwhelming majority of individuals, it is plain that the situation can only be held either by obligations from the strong to the weak voluntarily assumed or by obligations imposed frequently in hatred and maintained by force. A state can only recognize, rarely can it create, acceptance of obligations. We may undertake to recreate our civilization as free people, freely inspired by dynamic and powerful life; or we may meet the obligations which the time requires in a specie of servitude imposed on us by masters whose right is that they can assume the power and whose best distinction is that they are able to use it for a time in such manner that the machinery will work. Faced with this choice, there can be but one answer. But I submit that it requires faith to do this; and for that dynamo we must turn to men of the spirit, who are also trained in thought and no strangers to action. We need, at long last, men who are not afraid to say that certain things are wrong; that it is not only bad business but immoral to gamble with the peace of America in order to make a profit in munitions; who will say that it is not only unsound but wicked to gamble with the safety of individuals by putting together financial consolidations which have no chance of rendering a service commensurate with the obligations undertaken; that speculation in the grand sense is not only unsafe but sinful; that profiteering in wages at the expense of health or safety is not only bad economics but bad Christianity; that the enterprise which cannot succeed save by doing one or all of these things is an enterprise which has no right to exist and whose life ought to be ended, by law if need be, but in any case by the common moral sense of the community. We need to be told that when a business policy is adopted an offense against God has occurred unless those proposing and fostering it have looked through their technical papers and their theoretical calculations and have weighed carefully to the best that in them lies the exact effect which this will have on the lives of men and women. We need to realize that when a government policy is adopted, whether it be of taxation or regulation or what you will, it must necessarily translate itself into individual life and individual happiness and that this last calculation is the only calculation which really lasts.

We need something more. We need a faith that where to the extent of our limit said ethical obligations have been assumed and fairly lived up to, then there will be safety and strength. This is a hard thing to say at a time when belief in the providence of God is at so low an ebb. But I have noticed that individuals who do endeavor to keep their faith are likely to be what the world calls lucky; which is merely another way of saying that the things they endeavor to do are likely to be those things which are most in harmony with an underlying order of affairs. I do not think we need to go back to the conception that each individual has a private guardian angel to look out for him; I think we may take it in the large as in the little; and I think we may proclaim a belief that the strength to do and endure comes as much from within as without.

(*Please turn to page 169*)

FORESTRY AND THE CCC*

WILLIAM C. BRAMBLE
Carleton College

A new element in the forest conservation movement in the United States has been recently created in the form of a Civilian Conservation Corps. The effects of the activities of this Corps upon the practice of forestry have been so profound and of such a considerable magnitude as to make its establishment one of the most striking events in the history of forestry in the United States. Before we examine certain influences that the newly created element has exerted upon forestry, let us briefly survey the background of the present forestry situation in order to gain a conception of the inherent causes of the philosophical attitude of the United States as a nation towards the forestry movement, its "forestry philosophy."

The early settlers of the American Colonies came principally from the Old World where much of the land was heavily populated. Frugal habits and conservative instincts in regards to the use of nature's more important raw materials had been bred into them in their native lands, for even in those days much property in forest land in Europe was carefully tended. Historical records teach us that years of careful use had been extended to many European forests, particularly in central and northern Europe, although technical skill in forestry practice and management of timber holdings as we know it today had not yet been developed. The forest of Krumhubel in the Riesengebirge, owned by Count Schaffgotsch, is an example of an area which must have been thriftily used for several hundred years at the time of colonization of North America. Forest records on that estate may be found at the present time which extend back to the year 1593; while forestry activities such as yield regulation which is the prime aim of forestry practice, when perfected, because it leads to a balance between timber cut from the forest for use and replacement of the forest by growth, began in this large private forest about the year 1770. At the time, when the area now included in the United States was being populated, the Old World was thus teaching the lesson of conservation to its people, among whom were many whose lives were to be completed in the American Colonies.

From the background of Old World habits of frugality the early settlers came to a continent that abounded in vast forests. Endless tree-covered areas inhabited by wild beasts and wilder Indians were presented to their eyes as they viewed the New World from their tiny cabins and small clearings. Much of the land required clearing of trees before cultivation of food crops could be carried on by the settlers. Removal of thick woods about places of habitation were also advisable for protection against the savage inhabitants of the forest as well as for agriculture. The forest was valued primarily, and one might even add almost entirely, as an immediate source of material for building purposes and for fuel. Small wonder that the early settler soon came to feel that the evils

* A lecture delivered before the Sigma Xi Club of Carleton College.

of destruction and waste of the seemingly endless and threatening forests were a small matter compared to the acute need for cleared land and forest products! The traditional respect for the preservation and conservative use of the forest brought from the mother countries was soon supplanted by a feeling of disregard for conservative use, and even by a feeling of hostility towards the forest. This psychological effect of the forests of the new continent upon its early settlers became firmly imbedded in the minds of the people, and seems to have persisted for many years after all reason for such a viewpoint disappeared.

In the early days of our colonial history, some evidence of a desire for conservative use of the forests brought from the Old World was still to be found. This was exhibited through the medium of various laws and restrictions passed by the colonies, and, although this phase of forestry activity was transient in nature and passed away with further expansion of the country, it is of historic interest in connection with a survey of our forestry background. As early as 1653, authorities of Charlestown, in Massachusetts, forbade cutting of timber on town lands without permission from the selectmen. This example must have had some effect, for the neighboring town of Madden, in 1689, made unlawful the wasteful cutting of trees less than one foot in diameter for fuel. Our frugal puritan ancestors! A classic example of early colonial legislation is that brought forth under the leadership of William Penn, who in 1681 propounded an ordinance requiring that one acre of land be left covered with trees for every five acres cleared. What a pity that Pennsylvania as a state did not retain some degree of the far-sightedness of Penn and insure the permanence of its once extensive and productive forests! One only needs to travel through the scrubby hills of northwestern Pennsylvania and compare them with the scattered virgin forests in that same region to bring vividly to mind the difference that a little conservation would have made. Proceeding to somewhat later date, one finds that in 1804 the Massachusetts Society for the Promotion of Agriculture offered prizes for successful forest plantations to stimulate the production of needed material for local consumption. Similarly, in the early nineteenth century, federal protection was authorized to protect southern live oaks and cedar in Florida in order that a source of material for wooden ships for the navy could be insured.

With the passing of wooden battleships and the great expansion of the country, active interest in the early forestry endeavors ceased and there was no sign of a purposeful shaping of conservation or forestry movements in the United States for some years. Great increases in population, westward migration, rapid clearing of forest land for farming, and other factors soon overweighed the need, real or expected, to provide for local use of forest products or to correct local abuses. Out of the maze of conflicting legislations and ideas, however, there came in the late nineteenth century a concrete expression of forest policy which may be called the cornerstone of the concrete beginnings of forestry in the United States as it exists today. This cornerstone, to be found in an obscure little paragraph of the Act of 1891, provided for setting aside and reserving public lands wholly or partially bearing forests. A basis for a forest policy thus evolved out of a chaos of diverse laws and conflicting interests in regard to public lands; the way was opened for the fact of federal forest management.

Many years passed since the first groups of pioneers hewed at the forests in the expansion of a nation and an enormous amount of wood products were derived from them. The Act of 1891 began a series of intermittent forestry acts and measures which tended to slow down the devastation of a valuable national resource and to ameliorate its evil effects, but still the nation, in practice at least, avoided the accepted truism of more enlightened countries which states that any social or economic situation that tolerates the destruction of natural resources is basically unsound. As late as 1907 Gifford Pinchot wrote, "Except China all civilized nations care for the forest. Until recently the United States ranked nearly with China in this respect, and our country still remains far behind the progressive modern nations in nearly all that related to the protection, preservation, and conservative use of the forests." At the time the United States was bidding to lead the world in effectiveness and skill at destroying forests. Our lumbermen had developed extremely effective rapid methods for removing forest products, principally lumber, from the forested areas of the country. Methods that had as their sole aim the rapid and complete removal of merchantable timber without regard for the preservation of the forest for future use. Entire blame cannot be laid at the door of the lumberman for the early exploitation of our forests, however, and it cannot be said of them as a class that they were more greedy for gain or less careful of conservation of natural resources than other business men bent on securing a profit from the business of an expanding nation. There was simply a lack of knowledge as to the methods and advantages of conservative lumbering that would reduce waste and losses, and a lack of incentive to gain or use such knowledge. The weight of public opinion was not exerted towards encouraging conservation probably because the general public was itself profiting from the exploitation of forests, either directly or indirectly, and as a result the strongest among the conflicting attitudes of the nation towards forest conservation was that of condoning exploitation as a means of "opening up the country." It is not surprising with such philosophy of destruction prevailing in the nation, the preservation of forests formed a minor part of our early national activities. Forest conservation was destined to linger in the background of public affairs, smouldering in the midst of conservation groups, and kept alive by bursts of flame from intermittent acts and measures which mark the history of the forestry movement in this country.

It must be recognized when viewing the present situation that we have arrived in a space of about 200-300 years at a position in regards to the use and disposal of our forest lands somewhat similar to that which it took Europe something like 2,000 years to attain. Our arrival was brought about by a more rapid chain of events, and we are confronted at the present time with a different set of circumstances from that of Europe that will likewise effect the manner of solution of our problem. The two forestry movements are based on greatly different time scales and exist under profoundly different social and economic conditions. Such differences should be taken into account when the beginnings and future of forestry in the United States are considered. Notably different were the early beginnings of forestry in northern and central Europe from that in the United States. Much of the early practice of the conservation principle in Europe was

due to family power and pride, as well as obligations passed on from generation to generation of landowners and to desire for superior game cover among hunt-loving nobility. A tradition of forestry based on centuries of careful use led to a pride in well-tended forests and a fine exhibition of neat national housekeeping. Still, it is fair to say that the early traditional beginning of forestry does not tell the entire story of European forestry, and it is in the later history that we find the beginnings of modern forestry and more of a similarity to our own development. Not much more than 100 years ago there was a danger of a timber shortage in Europe in face of undeveloped transportation and prior to the development of the use of coal as a fuel. Not until that time, faced by economic necessity, did the forests of Europe as a whole come under productive management for forest products. Forestry in the United States seems to have lacked the stimulus of heritage of forestry practice from private landholders similar to that felt by European forestry. Our private owners have been, generally speaking, more engrossed in the problem of how to get profits from the forest in their short lifetimes rather than how to develop the forests and pass them on to future generations as productive areas. We have thus succeeded in utilizing or destroying the cream of our virgin forests without adequately providing for future harvests, in fact, many of the formerly productive forest areas have been practically ruined for generations to come. The presence or absence of actual timber shortage as an immediate danger seems to be a debatable matter, but the continued destruction of our forests, which not only decreases the possible future wood supply but also affects adversely the other beneficial influences of the forest on water, stream flow, erosion, and the like, is without question a matter for serious consideration. As a result, the present demands for forest conservation seem to be placing more weight on the argument that the forests should contribute to the national welfare through conservative use and development and act in giving livelihood to a portion of our population, not that it should be left idle as an insurance against wood shortage.

Recently a group of United States lumbermen and foresters interested in the forest problem of this country made a visit to the German-speaking countries of Europe for the purpose of making a general study of public forest policy both on public and private lands, and, also, to make an exploratory study of those aspects of central European forestry which would be helpful to America. This group was composed of lumbermen and foresters gathered together under the auspices of the Oberlaender Trust of the Carl Schurz Memorial Foundation. The comments of the party after their stay of approximately one year in Europe are exceedingly interesting. Perhaps the most universal comment was concerned with the attitude of the Germanic people towards forestry. Their philosophy was found to be quite direct and simple. Forests are an important part of the natural resources of the country and are highly valued both for their economic value and their beauty. It is expected by the general public that the forests will be cared for by their present owners and passed on to subsequent generations as a valuable possession, not devastated or despoiled but improved. Although such a philosophy may not be ideally achieved in practice even in the Germanic countries where it is exceedingly strong, its influence is strongly felt and cer-

tainly was evident enough to take hold of the minds of the visiting Americans as an outstanding difference between forestry in the United States and northern and central Europe. When one examines the attitudes of the United States towards forestry and the possible factors that might stimulate forestry practice in this country, one is encouraged by finding at the present time a strong feeling arising which has an interest in the accomplishment of conservation and a disapproval of devastation. A philosophy of conservation is being evolved which may develop into a deep respect for forests similar to that current in Europe, not borne solely on the fear of a timber famine, but on the higher plane of a national desire for conservative and economical use of land. "The country has been developed until it supports a strong nation; the task of rapid and destructive development has been accomplished; now for a national plan which will set the house in order for the best possible use of the land," are the thoughts that are now running through the minds of intelligent citizens of the United States. Recent legislation has given practical evidence of the newer national attitude towards conservation of forest resources. Some of these new measures aim at reducing the destructive lumbering; others at improving the condition of forests already cut over and under protection of the conservation authorities. Prominent among the latter type is the Civilian Conservation Corps, commonly referred to as the CCC.

The creation of the CCC by enactment of Congress in 1933 is now a historical fact. The message of the chief executive proposing legislation to help relieve distress, to build men, to accomplish constructive results in our vast Federal State, and private forest properties was a part of a giant national emergency conservation work program; a part which has been felt in nearly every corner of the United States. The establishment of the CCC called forth some 300,000 men from the ranks of the unemployed and put them to constructive work under healthful conditions. A great deal has been said since the CCC swung into action concerning the effects of the life in the camps upon the young men living therein, and rightly so, since it is the relief of human distress and the building of men that form the basic keynote of the entire program. We have thus become familiar with some of the striking benefits effected by the CCC in the matter of improving the health and even the character of men. But what of the effect on the forests? The legislation which created the CCC also states as one of its keynotes that it shall endeavor to "accomplish constructive results in our vast Federal, State, and private forest properties." It seems fitting, therefore, that one should inquire as to the effects of the men on the forest, as well as the effect of the forest on the men.

Prior to the installation of the CCC as a working unit in the forests of the United States, economic pressure had permitted only the most urgent and necessary activities to be performed in the course of forestry programs, although forest officers had long regretted their inability to do things to abused forest land which their common sense and training had indicated to be desirable. Forest lands had been obtained which were in various conditions, many in a deplorable state. As these lands were incorporated into forest units and protected to the highest degree possible with the limited funds made available, little could be done to

improve their timber and protective value by forestry treatment. The maximum benefit, or an approach to the maximum, from the forests could not be derived under those conditions; and forestry was carrying on under minimum activity in so far as actual forestry practice was concerned.

Some information and a few plans for forest management were being accumulated even during this inactive period for use at a time when the need for technical forestry practice would be realized and its practice encouraged to build up forest areas to serve as a constant source of labor and forest products. Most of these early plans, however, remained simply as matters of technical interest and rested as dormant seeds in office files or as dreams in the minds of men. Then, suddenly men and funds were made available for forestry activities by the emergency conservation program and the resulting deluge in 1933 broke the dormant period of forestry to bring about a spring of activity. Plans were dug out of files and revised to fit the needs of the emergency; new plans were evolved. Forestry began to leave its dormant stage to burst forth into a vigorous growth.

Despite the apparent suddenness of the action taken by the President and Congress in the spring of 1933, the proposal of a conservation program as a national policy was not, as it might seem, the result of a sudden and unpremeditated decision. In the United States there had been a trend of thought towards such action existing over a considerable period of years. The writings of William James in 1910 and George H. Maxwell in 1915 are examples which outlined programs for concerted action against the forces of nature by the enrolled youth of the country. At least one former President of the United States had spoken of the possibility of the need for such a program, while the present executive is reputed to have been shaping the idea for a number of years.

In Europe, a similar undertaking known as the Bonifica Integrale, had been in effect in Italy since 1928. The Italian program had as its aim the conservation, reclamation, and utilization of the nation's soil and water resources and already had shown its efficacy in improving natural resources as well as relieving the strain of unemployment. The problem of improving natural resources upon which man depends for his basic supplies and the problem of building up the moral and physical strength of the people had already been seen as a problem of civilization to be solved by intelligent nations. Prominent among other countries engaging in forestry or other conservationist activities on a national scale was Sweden whose forestry enterprises for the benefit of the unemployed had been begun at about the same time as the program in the United States. We found ourselves, therefore, moving not alone in a new and untried experiment but as one of an international group acting to improve the health and welfare of its people through increased interest and activity in conserving one of the greatest natural resources, the forest.

When the proposed work program of the CCC is scrutinized carefully by a first-hand observer, a large portion of that program will be found to consist of work commonly referred to as administrative, that is, work which has to do mainly with the improvement of the administrative units and activities of the forests. Such projects as the construction of roads and trails, roadside clearing, building of bridges, lookout towers, fences, and other similar activities which

increase the efficiency of use and control of the forest areas may be included in that group. The fighting of forest fires and work related directly to their control may also be termed administrative projects. On the other hand, there is a second general type of work included in the program which may be termed technical forestry practice. It is this latter type of forestry activity only that we will consider at this time, although one should recognize that while the two types of activities may be theoretically distinct, they each exert an influence upon one another and blend together in a well-rounded forestry program.

The simplest way to gain a conception of the new scope of technical forestry under the conservation program is to review the types of such work which are made permissible. The list of this work serves to indicate the phases of technical forestry work, most of which have been brought out of the realm of theory into practical application for improvement of forested areas, undertaken by the CCC. It may be summarized as follows (1) Improvement of the timber stands by thinnings and removal of undesirable trees; (2) forest planting; (3) controlling the attacks of the forest tree diseases; (4) controlling the attacks of insects which are harmful to forest trees; (5) eradication of rodents destructive to forest growth; (6) forest timber surveys to further the general development of forest lands; (7) control of soil erosion.

During the course of the program, planning and supervising technical forestry enterprises such as cultural treatment of forest stands, control of insects and diseases, and the like soon became an acute problem, and selection and employment of trained foresters for the handling of much of this specialized work was necessary to meet the situation. This brought a number of men into active work, most of whom had been trained in forest schools but had been prevented using the training given them because of depressed economic conditions. A great deal of preliminary work of a technical character was done by these trained foresters for the purpose of locating areas which would be benefited by stand improvement measures such as planting, weeding, release cutting, pruning, and sanitation cuttings. From the results of preliminary surveys, working plans to meet the need of the CCC camps were laid for each of the areas so that the various improvement measures could be carried on contemporaneously in such a manner as to place each forest stand in its best possible growing condition. Trained foresters, or men skilled in working in the woods through experience, were then assigned to each camp to supervise the forestry projects.

The planning of forest conservation work is one of the pleasant facts to be recorded to the credit of conservation forces in connection with the present emergency program. Under the boom created by the advent of thousands of men and funds for extensive work into their jurisdiction, there was inevitably a temptation to take advantage of the situation by undertaking a number of purely technical forestry projects of uncertain practical value. Such temptation was avoided, however, and vigilant scrutinizing by directing forest officers was given to all work projects to insure the elimination of all those projects that could not be shown to be of definite value to the particular forest area for which it was designed. It was evident that many projects, which are desirable for certain forest stands in particular, would be of uncertain value when applied

to stands in general. With this fact in mind, forestry kept both feet on the ground in the midst of the staggering tide and put its best efforts into serving the interests of the nation through careful planning of work projects.

For concrete examples of how the CCC has affected technical forestry practice, let us examine the condition as it exists in several of the forest regions of the United States. Timber stand improvement in the Southwest had been formerly regarded as possible of attainment only in the distant future, and although the forester had been experimenting with improvement methods for five years or more in order to gain and store information, technical forestry work was yet in its infancy. Into this situation in 1933, a tide of manpower beyond the dreams of forestry officials was released for use in applying silvicultural treatment to forest stands. A combination of the results gained from experimental plots with practical observations made by the foresters was used to lay out the first plans for increasing the productivity of the forest areas. This plan called for a general thinning operation which removed certain trees, particularly diseased and defective trees, in order to increase the volume and quality of timber produced in the future by the trees left to form the final crop. Approximately eighty trees were left on each acre of land as crop trees. After these preliminary plans were laid, the work went ahead and the CCC developed into a coherent working body. The early plans served their purpose, but after the first year improvements in the methods used were made based on past years' experience. The general thinning method was discarded in favor of a modification in favor of restriction of felling to the release of crop trees and removal of diseased and defective trees. The trees left for the final crop were pruned to a height of seventeen feet to remove dead branches, and, thus, increase the quality of the wood by reducing the number of knots that would otherwise be formed. This modification resulted in a lighter thinning over the forest areas in general. As a result of such modifications, the experimental plans evolved into something practical, and development of forestry methods took place as the trained forester for the first time was able to see the actual practice of silviculture performed and tried "under fire." The result has been an evolution of silvicultural methods which has placed forestry on a sound practical basis that could not have been attained for years under former static conditions. Conservative estimates based on the improved methods indicate that the stand improvement applied to suitable forest stands and sites will return its cost at a low rate of interest. Not only has the present practice been approved, but also the foundations for the future been laid in the form of sample plots that will answer many questions concerning forestry practice. Questions such as the number of trees to be left for a future crop, how much and how frequently the trees should be released from the competition by removing surrounding trees, and at what age should cutting to improve forest stands begin in the Southwest may be answered from the results of the present program.

In the North Central States Region, a considerable amount of stand improvement work was put into practice, using the CCC as working units to place the forests in good, thrifty, growing conditions. This work included planting, weeding, release cutting, and pruning. To these may be added disease and insect

control. Although such timber stand improvement work has been conspicuously absent from the region in the past, basic principles and silvicultural practice elsewhere in the United States and Europe were revised and adapted to Lake States conditions by trained and experienced foresters. A strong initial program was initiated and already much has been accomplished in technical forestry work that will be of real value to the forests. An example of how the effects of cultural treatment may benefit the forest areas so treated is to be found in the results of an experiment of the Lakes States Forest Experiment Station on the cutting of aspen to release young Norway pine from the competition which occurs when aspen and pine grow side by side in the young forest. The experimental release cutting not only freed the pine from undesirable aspen competition which threatened to eliminate the first-named species, but also increased the diameter growth of the Norway pine on the released plot nearly two and one-half times that to be found on similar untreated areas. Even trees which had been overtopped and suppressed by aspen responded well to the release cutting.

A third example of the effect of technical forestry practice may be found upon areas in the high Sierras of California where red fir forms a valuable source of Christmas trees. The young firs appear in clearings created mostly by windfalls of older trees, and often spring up in pure thickets. Where the growth is too dense, as is usually the case, overcrowding is apt to occur which will result in poorly formed trees not suitable for Christmas decorations. The forester with the aid of the CCC has been improving such Christmas tree areas by thinning and weeding the dense thickets formed by the red fir reproduction in order that the remaining trees may develop without crowding into well-formed Christmas trees. The improved treatment thus afforded the areas should result in an increase of well-being and economic value of tree crops produced on them.

When one reviews the results accomplished by the CCC as measured by its effect on technical forest practice, the most outstanding result of general interest, in addition to the constructive work accomplished, is the manner in which the planned improvement of forest areas has been brought to the direct attention of both the forester and the public. The forester has been brought face to face with the necessity of actually applying in a practical fashion measures that had been existing in an experimental stage, and forestry activities such as those previously mentioned as being of a technical forestry nature have been adapted for practical application for the first time in the history of forestry in the United States in connection with the program of the CCC. A real need has been seen for the development of major control plans to guide these technical forestry activities of the CCC. It was not sufficient that forest regions be improved by haphazard application of silvicultural measures here and there over the forest areas, those practices had to be organized under a plan which had certain definite objectives so that the program as a whole would be coherent and generally constructive. Such objective master plans have rapidly been taking form in the various forest regions of the country, and the movement gives promise of evolving a standard of forestry higher than has been attained in the past and one that is fitted for the conditions peculiar to the United States. We seem to be headed

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THE PROBLEM OF THREE BODIES

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There are many problems of mathematics which have become famous because of the unceasing, persistent attack which mankind has directed against them. These problems have presented great resistance to almost all methods of attack, but the curiosity which is a part of the nature of man will not allow him to stop.

There are five such problems which seem to me to stand out from the others so much that they deserve special mention. The five I have in mind are the following:

1. The trisection of any angle which is not an integral multiple of a right angle.
2. The construction of a cube which has twice the volume of a given cube.
3. The construction of a square which is equal in area to a given circle.
4. Fermat's last theorem: There is no integer, n greater than two such that $x^n + y^n = z^n$, x, y and z being integers.
5. The problem of three bodies.

The first three of these have been completely solved but only after more than 2,000 years of effort! The last two are not yet completely resolved but we have been working on them only three hundred years!

The problem of three bodies can be stated very easily. Given three spheres, homogeneous in concentric layers, of masses m_1, m_2 and m_3. Place them at random in space and give to each a velocity of any size whatever in any direction. Find the curve in which each body will move and where each will be at any future time.

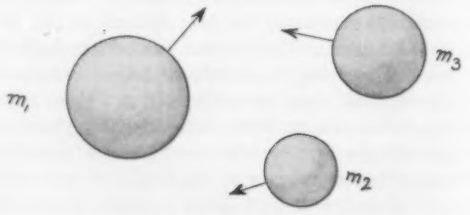

FIG. 1

We may visualize the problem easily from figure 1. The arrows indicate the size and directions of the velocities. We suppose that Newton's law of gravitation provides the only forces acting. According to this law each body is subject to two forces; m_1 is attracted by m_2 by a force which is proportional to $\frac{m_1 m_2}{r_{12}^2}$ and m_2 is pulled toward m_1 by a force proportional to $-\frac{m_1 m_2}{r_{12}^2}$, r_{12} being the distance between m_1 and m_2. The forces acting between m_1 and m_3 are

respectively proportional to $\frac{m_1 m_3}{r_{13}^2}$ and $-\frac{m_1 m_3}{r_{13}^2}$ and finally the forces between m_2 and m_3 are proportional to $\frac{m_2 m_3}{r_{23}^2}$ and $-\frac{m_2 m_3}{r_{23}^2}$.

There is a well-known law of physics to the effect that "mass times acceleration equals force." Applying this law to each of the bodies we may set up mathematical equations which determine their subsequent motions. Now the real difficulty begins. All the ingenuity that mathematicians have has been turned on this problem for the last 250 years. Nearly every mathematician of note has tried his hand at it. Many special cases have been solved but no complete solution has been attained. The problem certainly has a solution. The trouble is with our mathematics.

The difficulty which we encounter in the three-body problem is a little surprising when we consider the ease with which the two-body problem was solved. Newton solved the latter problem almost immediately after he had developed the calculus, the tool with which all such problems are attacked. The solution of the two-body problem can be stated in a single sentence: Two bodies, m_1 and m_2, will move in an ellipse, a parabola, or an hyperbola about their common center of gravity. The most common case is the ellipse. All of the planets of our solar system move, approximately in ellipses. Most comets move in hyperbolas, diving around our sun once and moving off again never to return, while a few comets move in ellipses.

The first man to obtain a particular solution of the three-body problem was Lagrange. In 1772 he found several particular solutions. One of his special cases was that in which the three bodies remain in a straight line and revolve in circles or ellipses about their common center of gravity. This may be illustrated very nicely by placing three balls on a rod and rotating it.

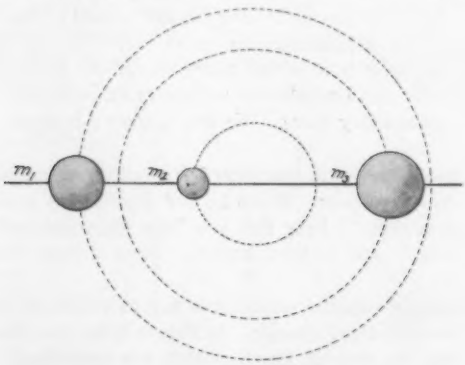

FIG. 2

The attractive forces between the bodies are exactly balanced by the centrifugal forces resulting from the rotation. The body m_1 may be as shown in Figure 2 or it may be between the other two, or to the right of m_3.

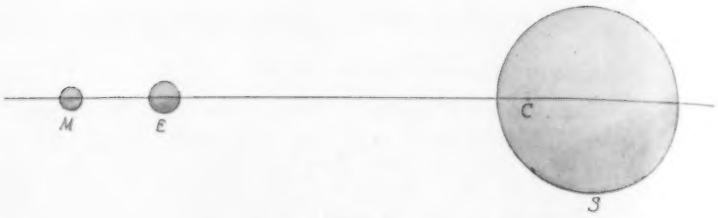

FIG. 3

Let us suppose for a moment that the three bodies are the sun, the earth and the moon. To be definite let m_1 represent the moon, m_2 the earth and m_3 the sun. The drawing is not to scale for the distance from m_2 to m_3 should be about 100 times the distance from m_1 to m_2 and the diameter m_3 should be 110 times that of m_2. It is impossible to get on paper a drawing to scale. However, the figure will enable us to see that if the moon is placed on the side of the earth away from the sun at exactly the proper distance and each of the three bodies be given exactly the proper velocities then the moon would always remain on the side opposite to the sun and hence we would always have a full moon.

Laplace, a contemporary of Lagrange, wrote a book entitled "L'Exposition du Système du Monde." In this book Laplace remarked that the creator of the solar system did not show much wisdom in its construction for the moon could have been placed at the equilibrium point opposite from the sun and thus provide continuous full moonlight to the dark side of the earth. There are two fatal defects to this idea of Laplace. One is that the point where the moon must be placed is nearly one million miles from the earth. That is four times as far as our moon is from the earth. Our moon if placed at that distance would appear about the size of a Louisiana orange or more exactly about one-fourth the size of the moon as it is now and hence would not give much moonlight. The other defect is one that Laplace was not aware of, namely, if the moon were placed there it would not stay there. We will discuss this phase of the question later.

Laplace was an atheist. He considered it possible to explain all celestial phenomena from Newton's laws. When he had finished his book he took it to Napoleon. Napoleon said, "I hear that you have dispensed with God in your new book." Laplace is said to have replied, "Sire; I have no need for that hypothesis."

Another of Lagrange's special solutions is that in which the three bodies are at the vertices of an equilateral triangle. In Figure 4 we show how this triangle may be rotated with the correct speed so that the centrifugal forces exactly balance the mutual attractions. The triangle revolves about its center of gravity c. Each body is attracted toward the other two by forces whose size is indicated by the arrows. The resultant of these two forces is balanced by the centrifugal force. Lagrange also found equilateral triangle solutions in which the three bodies move in ellipses.

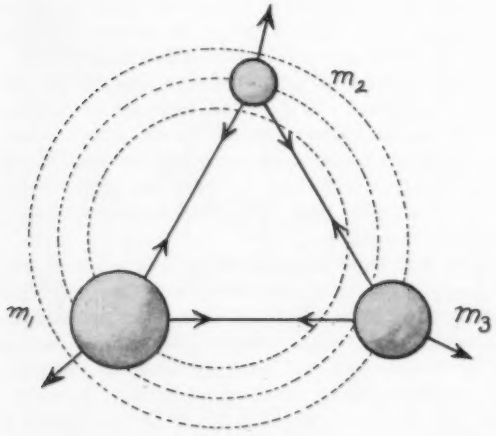

FIG. 4

With Lagrange's work accomplished the problem of three bodies remained stationary for seventy years. It is true that much important progress in the application of celestial mechanics to the computation of the orbits of comets and asteroids and to other problems in perturbations but these are not true solutions of the problem of three finite bodies although they are much more used than the special solutions of the problem of three finite bodies which have as yet been found.

About seventy years after Lagrange, Liouville showed that the straight line solutions of Lagrange were unstable. Since we shall use this idea of stability or instability several times it will perhaps be wise to explain it. A very simple example will suffice. Suppose we have two wires bent as shown in the figure.

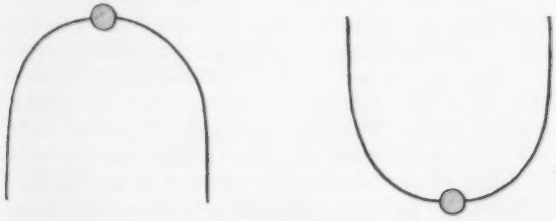

FIG. 5

Let a ring be placed on the right wire at the bottom. If it be disturbed a little bit it will oscillate back and forth along the wire till friction brings it to rest. If there is no friction it will continue to oscillate. On the other hand it is possible to place a ring on the left wire at the top so that it will stay there but if it

be disturbed ever so little it will leave and never return to that position again. The ring at the bottom of the loop is said to be in stable equilibrium while the one at the top is in unstable equilibrium. When Liouville, in 1845, showed that the straight line positions of Lagrange were unstable he uncovered a fact that was unknown to Laplace. If the moon were placed opposite to the earth from the sun and the system rotated with exactly the proper speed the formation would be broken up by the disturbances introduced by the other planets and the three bodies would depart to orbits very far away just as the bead in the unstable position at the top of the wire does. Thus the Architect of the Universe was not as stupid as Laplace thought.

It is well known that there is considerable loose material in interplanetary space. This is brought clearly to our attention by the number of meteorites, commonly called shooting stars, which are seen in our atmosphere every night. Indeed there are just as many striking into it in daylight but we cannot see them.

Professor H. A. Newton of Yale University calculates that there are between fifteen and twenty million striking the earth every day. It would seem reasonable that quite a number of them would arrive at the equilibrium point opposite from the sun with nearly the proper velocity to stay there and hence might take several turns about this point before leaving. This is borne out by observation for there is a faint glow at that point known as the gegenschein or opposite glow which has been observed by Backhaus, Brorson and Barnard.

Many of the investigations since Liouville have centered about the so-called restricted problem of three bodies. In this problem one of the masses is regarded as so small that it does not affect the motion of the larger ones but is affected by them. Of course, strictly speaking, there is no such body but the approximation is close and some very useful results have been obtained. In this restricted problem of three bodies the equilateral triangle positions are stable if certain mild restrictions on the two finite masses are satisfied. The investigations on the restricted problem were begun by Poincaré and have been carried on in this country by Moulton and his students. There is always the question as to whether or not their results are correct since there is no body so small that it does not have an effect on the other two, however large they may be. This was brought out in a paper published in 1927 in the *American Journal of Mathematics*. In this paper the stability of the equilateral triangle positions was investigated for three finite masses and the condition which must be satisfied is much more general.

The problem of possible periodic oscillations near the straight line and equilateral triangle positions has been investigated in a series of four papers appearing in the *American Journal* from 1923 to 1928. Six new types of special solutions were found. These are the first solutions of the three-body problem since those of Lagrange. In papers published in 1923 and 1925 in the *American Journal* three types of orbits were found near the straight line positions. One of these is shown in Figure 6. In this figure m_1, m_2 and m_3 are the three bodies in the straight line positions and c is the center of gravity. It was shown in the papers quoted above that the bodies could be given such velocities that they will trace out the curves shown and they will return to the starting point simultaneously. These curves are ellipses when viewed from the top of the page, they are

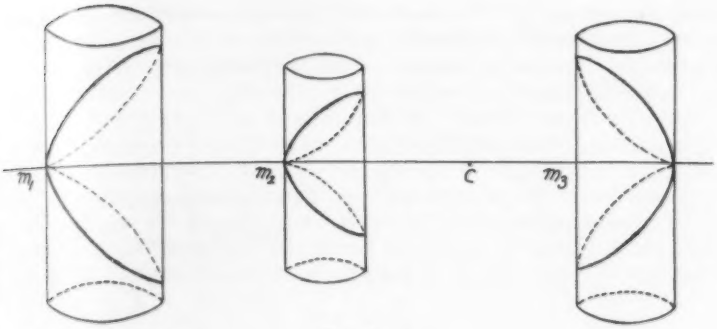

FIG. 6

parabolas when viewed from such a position that the back and front parts coincide and from any other position they are like the Figure 8 bent in the middle. A good idea of the shape of these orbits can be gotten by wrapping a string about a cylinder twice, holding the two together on one side of the cylinder while pulling them apart on the other. One must remember that the whole configuration is turning while each body traverses its figure eight.

Another type of orbit near the straight line positions is a plane orbit in which each body traverses an ellipse while the whole configuration is making one revolution. The plane of this orbit may be inclined to the original plane but each body traverses an ellipse and they return to the starting point simultaneously.

The third type of orbit found in the papers of 1923 and 1925 is like that mentioned above but the period is shorter. In both of the latter type the orbits are entirely in a plane but the orbits of the type shown in the figure are space orbits which are not in a plane.

In the two papers published in 1927 and 1928 the possible orbits near the equilateral triangle positions were investigated. Again three types of orbits near these positions were found. Their characteristics were quite similar to those near the straight line positions. Thus in all six new particular solutions of the problem of three finite bodies have been found.

After the equilateral triangle positions for the infinitesimal body had been investigated and it had been found that the position was stable if m_2 $l.03$ m_3 most astronomers assumed that the situation was not changed if all three bodies were considered finite. In a paper published in 1928 the exact conditions for stability were discussed. It was found that unless a very stringent condition on the relative sizes of the three bodies was satisfied that the position was unstable. However, an interesting case arises in the case of Jupiter, the sun, and any of the small asteroids. This condition on the masses is satisfied for three such bodies and the equilateral triangle positions are stable. One would expect then that there ought to be one of the largest concentrations of small bodies in our whole solar system at the equilateral triangle positions. Observation again bears out this theory and in the last few years there have been discovered five

planetoids large enough to be photographed through powerful telescopes at one of the equilateral triangle positions of Jupiter and the sun and four at the other. The nature of these is shown in Figure 7. It will be interesting to observe where these

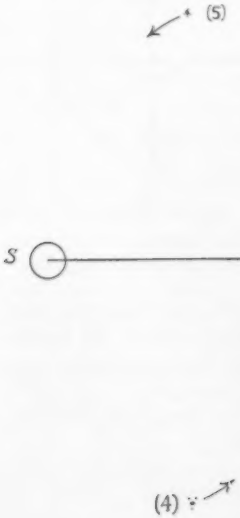

FIG. 7

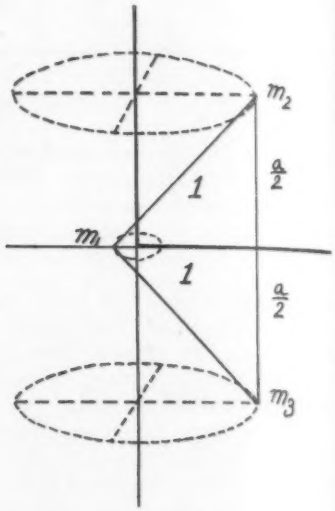

FIG. 8

will go when the configuration is finally broken up as it is nearly sure to be in the course of time by the disturbances produced by the other planets.

We turn our attention now to a different type of three-body problem. This is known as the helium atom because it was used by Rutherford and Bohr more than twenty years ago as a possible model for that type of atom.

It consists of a central nucleus of mass m, charged with a positive charge of electricity l, and two electrons of mass m_2 and m_3 with negative charges $-l_2$ and $-l_3$. Each electron is attracted toward the nucleus by forces $\frac{k^2 l_1 l_2}{r_{12}^2}$ and $\frac{k^2 l_1 l_3}{r_{13}^2}$ respectively, but the two electrons repel each other with a force $-\frac{k^2 l_2 l_3}{r_{23}^2}$. In addition the gravitational forces between the masses are also present.

The originators of the idea probably had in mind the straight line positions in which one electron is on one side of the nucleus and the other electron on the opposite side. The stability of this situation was examined recently in a paper which appeared in the *American Mathematical Monthly*. It was found that the position was unstable. Any disturbance from outside forces, however slight, would cause it to break up.

A more interesting special solution of the helium atom is the equilateral triangle solution. This is quite different from the equilateral triangle solution of

the problem of three bodies where the three bodies revolved in their own plane. Here the three remain at the vertices of an equilateral triangle but this triangle revolves at right angles to its own plane. One member of the Tulane Mathematics Department has generalized these equilateral triangle positions and proved that there are isosceles triangle solutions. Figure 8 shows his solutions.

Papers discussing the existence and stability of these special solutions of the helium atom problem have been published and are in preparation. It has been found that all these positions are unstable. The physicists abandoned them years ago as unsuitable for models of the atom but the insatiable curiosity of the mathematician will not allow him to quit till a lack of suitable mathematical theory or old age forces him to stand aside and let younger men try their mettle.

Lasting Values in Government

(*Concluded from page 152*)

We shall need every resource of technique and of thought and of strength if we are to weather the very obvious streams through which we must sail before most of us have seen our final sunset. It is no affair of the next generation we have to discuss. I think I could demonstrate it by statistics if the article were for that purpose. My point is that the strictly materialist's conception of civilization has run its course; and that the chaos of it and the terror of it already appear while men seek refuge from that chaos in brute strength and in the vague hope that a slavery to their strength will be more desirable than slavery to blind and nameless economic forces. Yet modern civilization has been through such crises before and has withstood them by calling forth a great faith in the ancient truth we profess; and by believing in that truth so strongly that it enforced at once thought and action and created strength adequate to meet the crisis.

Government is just now the stake of the play; contending forces striving for it as the fulcrum on which all levers must be turned. I hold that in that contest the only permanent values which can be achieved are those which must be attained by a reaffirmance with full faith in the ancient strong Christian forces of faith and love.

THE SCIENTIFIC ATTITUDE

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It is fitting for scientists as individuals or in groups to consider the essential features which are characteristic of the mental attitude of a scientist and which are the result of his natural inclination, his training, and the nature of his subject, features which may be distinctly different from those of persons trained in other fields of endeavor and which mold his character, thus affecting his treatment of problems outside the field of science.

On first thought it may seem that one of the most distinguishing characteristics of his mental behavior is that because of his training he is peculiarly observant of natural phenomena and cognizant of the need to explain them. But is he, as a matter of fact, more cognizant of this material, which is the basis of his field, than is the historian of events and conditions in the past and present and the desirability of finding explanations of their causes?

Undoubtedly the scientist has a natural aptitude for recognizing the interrelations between phenomena treated in different parts of his own field and in the fields of his colleagues. But that is also true of the expert in any of the other fields of thought.

It is a fact that the scientist is unwilling to accept any theory without ample experimental verification of the ideas involved. This attitude and the acquiring of the experimental technique necessary for the work is the very heart of his training. But is not this attitude closely analogous to that of the economist or the historian, who must have frequent access to the sources preserved in government documents and museum material?

The scientist is, without question, a rigorous thinker and always insistent upon determining the cause of every effect in so far as the laws of nature permit; he has at his disposal means for testing his theories in ways determined by his own judgment and the facilities of his laboratory. He can repeat his experiments and vary the conditions as often as he chooses and his results are reproducible. The scientist is not hampered as are the followers of other professions by being limited in the verification of theories by the fact that all documents deal with past events and that the circumstances can never be reproduced. Usually the student in other fields finds that the verification of theories is limited by the incompleteness of the documents available and the fact that they all deal with past events which can never be reassembled.

Although I recognize that probably the most outstanding distinguishing feature of the scientific method is the experimental approach to the problem treated, yet I think that I should select as the trait in the mental attitude of the scientist which is not always apparent in the mental attitude of those in other fields, his liberal-mindedness, his willingness to consider all sides of a question, to reserve his judgment, and to have his preconceived ideas contradicted by new experiments, coupled with his constant abnegation of self in the pursuit of the truth in nature.

Over and over again the scientific world has witnessed some outstanding scientist persuaded that the theory he had enunciated and for which he had experimental evidence has been overthrown by later experiments and that new philosophical tendencies in his field have forced him to accept another point of view at variance with his previous ideas, or more complete than them. Usually the final formulation of a theory embodies the best features of those which have preceded it. I believe that the ability and inclination possessed by the scientist to make these transitions in the theories of his field, and that the ease with which he usually maintains a liberal attitude when treating problems outside his sphere, is one of the contributions which he makes to the educational world.

Open-mindedness and the ability to willingly lead one's thoughts through new channels is characteristic of all scientists and has made possible the rapid development of scientific thought and the discoveries which are particularly characteristic of this age. It would be possible for me to quote many illustrations to support these statements from developments in the field of physics, the science in which I am most conversant. I would mention a few of them.

One of the most fundamental changes in physical thought during the last decade has been in the physicist's conception of the nature and behavior of fundamental material particles. The character of the elementary, negatively charged, electrical particle, the electron, was studied in the last few years of the nineteenth century and during the first of the twentieth century; and in certain experiments for which Sir J. J. Thomson was most responsible it was determined that the electron is a material particle of very small mass, bearing a negative charge. The charge was measured with a high degree of precision in Millikan's beautiful experiment, which like all final experiments was a refinement and culmination of the work of preceding investigators, using a method which demands that the electron behave as a particle.

Then ten years ago both experimental and theoretical developments brought forth what seemed contradictory ideas. For Davisson and Germer in this country and G. P. Thomson in Scotland nearly simultaneously proved that the electron behaves like an electromagnetic wave when an electron beam is caused to penetrate a thin foil. Diffraction effects similar to those caused by short electromagnetic waves were produced.

In consequence the physicists found themselves in the dilemma of realizing that the electron possesses a dual nature, for in experiments, performed by the school of physicists represented by Sir J. J. Thomson, the electron behaves as a material particle; but in the experiments, performed by the group to which his son, G. P. Thomson, belongs, the electron in motion is clearly connected with an electromagnetic wave of definite wave length. In one of the annual Sigma Xi lectures A. H. Compton has described the dramatic moment which he witnessed when the father first saw his son's convincing photographs and was filled with enthusiasm in recognizing their implication.

In the last few years physicists have been endeavoring to reconcile the two phenomena. They have been assisted by a similar dilemma connected with the behavior of light waves. Under certain conditions it is necessary to explain optical phenomena by considering that light consists of non-material corpuscles,

called photons, carrying definite quanta of energy; with this quantum theory can easily be explained radiation effects and atomic heats, two of the outstanding failures of classical physics, and with it the photo-electric effect and allied phenomena can be easily understood. On the other hand it is impossible to use a theory involving discontinuous radiation of energy to explain diffraction and associated effects. So the physicist was forced to endow the carrier of light energy with a dual character some years before similar puzzling results were obtained in electron diffraction.

Simultaneously with the completion of these latest experiments occurred the enunciation of theories of wave mechanics, which were developed from the conviction that the same principles and idiosyncracies characteristic of the propagation of light must hold for a material particle. The names of DeBroglie, Schrödinger, and Heisenberg are those of pioneers in the theories of quantum dynamics. In the first five years of the last decade it required almost heroic effort and real denial of their faith in previously stated theories for physicists to make their minds receptive to the inevitable results. Much difficulty was encountered in understanding the mathematical tools which were used in the theories, and which were not wholly perfected. But because the evidence is so irrevocable all physicists have accepted the change in their point of view.

The same revolutionary theory has affected the elegant explanations of atomic radiation, in which the Bohr theory had all but succeeded in the previous decade. Making use of the quantum theory Bohr developed a theory which demanded the existence of stationary states, in which the electron was in equilibrium, and visualized elliptical orbits for the electron as it revolved around the nucleus as a planet does around the sun. The theory furnished means for the determination of the energy of the electron on these orbits, and for the first time spectral phenomena was almost satisfactorily explained. But Bohr, himself, was troubled because the theory did not always give the exact answer. Something was wrong and just before the enunciation of the theories of quantum dynamics he was prepared to make extremely drastic changes in his theory. The new theory has succeeded, with the sacrifice of the belief in the reality of the Bohr orbits, but making use of many of the accompanying features of his theory.

At present physicists are outstandingly liberal-minded. Formerly they believed implicitly in the particle nature of the electron; now they know it possesses a wave character; formerly they believed in an ether that filled all space and which was the vehicle for the propagation of electromagnetic energy; now they find that relativity theory explains effects where an ether theory failed. The question is raised: How can electromagnetic waves be propagated without an ether? The physicist does not know the final answer to the question, but he is convinced that the answer will be found; as additional clues come he will readjust his conceptions of matter and of energy to bring them in line with the new results.

An analysis of the isotopes of elements by the positive ray methods of Ashton and Dempster has established the fact that the hydrogen nucleus, known as the proton, plays an important rôle in the formation of the nuclei of the heavier

atoms. In fact it was considered established that these nuclei consist of protons and electrons closely packed together, for these two were believed the two elementary particles of the universe. Then, suddenly, the existence of the neutron, a neutral particle of approximately the same mass as that of the proton, was established, and it was necessary for the chemist and the physicist to revise their notions. Soon came the discovery of the deutron, the heavier proton of hydrogen, for which Urey is so largely responsible. About the same time, the mathematical physicist, Dirac, working in quantum dynamics, pointed out the necessity for the existence of a positive electron of the same mass as the negative electron. The particle had never been observed and its prediction was a stumbling block in the ready acceptance of Dirac's theory, when unexpectedly Anderson, who was studying tracks made in cloud chambers by cosmic rays, found some which could only be attributed to the positive electron, now called the positron. They were produced when high speed rays, *i.e.*, photons of high energy, collided with neutrons. In these experiments not only was the existence of a fourth elementary particle established, but for the first time definite evidence of the transformation of energy into matter was obtained. On learning of these experiments the physicist was forced to accept two radical changes in his preconceived notions. There exists a positive electron; and the equivalence of matter and energy, predicted by Einstein, has been proven by reversible transformations from one to the other.

I might take time to describe the effect on the mind of the physicist of the acceptance of the principle of uncertainty, and his still suspended judgment about theories of the expanding universe. But enough has been mentioned of the problems recently faced by the physicist to indicate why he is so outstandingly liberal-minded.

I know that every field of science is in a similar state of flux. Every day the scientist is nearer a knowledge of the truths of nature. Theories held twenty-five years ago are altered; seldom is any theory completely discarded; much of it and the experimental results obtained from using it are embodied in the new formulation. So does science progress. Each new achievement is a stepping stone to the next. Each man's discovery is a clue to the solution to another man's problem. Because of his scientific attitude each worker shares his results with others and eagerly welcomes whatever changes and developments may lead to a better understanding of natural phenomena.

AN ADVENTURE IN EDUCATION

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When one speaks of education, the thought usually relates to young folks or youngish folks, even through no individual's education ceases (by means of reading, contacts and experience) until he withdraws from all active relations with his fellow-men. In this article I will be emphasizing the organized terms of education for young folks who are undergraduate and graduate students in the engineering schools and other schools of science, but I will not overlook the continuous influence on the older men who are members of teaching staff. Usually in engineering, most of the students are men. My experience has included a few young women as electrical engineering students. They have done credit to their sex and their ambitions. However, when a man turns his thoughts toward his wife, he should become a poet, and this influence disturbs the rigor of one's judgment regarding any woman's wish to enter upon the varied trials of an engineer's life. I will, therefore, confine my remarks to education planned particularly for the males of the species, although women are welcome to come into it if they desire to do so.

Perhaps I should include a few words in the way of credentials before setting forth definitely on our adventure.

While a young engineer in the employ of the Edison General Electric Company supervising the design, construction and operation of electric power plants, electric railways and electric distribution systems of importance for their day, I was offered the post of head of the newly established department of electrical engineering at the University of Wisconsin. This was in 1891. No curriculum had yet been there established. The field was open. The authorities of the University had not yet determined whether the electrical engineering department should go hand in hand with the long-established department of physics in a manner then usual in electrical engineering courses, or should become a department of engineering *per se* and be closely associated with the civil and mechanical engineering departments which were of old standing in the University. Being a youthfully ardent engineer I promptly arranged for my lot to be thrown in with the engineering professors. I think that this was the first electrical engineering department to be originally set up in this country as a department of engineering instead of as an offshoot of a physics department. Certain older electrical engineering courses (for example, the one at Cornell University) had been transferred previously to full fellowship with other engineering departments although originated as offshoots from physics, but it was still customary for physics departments to maintain their paternity for electrical engineering. It was not until 1902 that the oldest of the electrical engineering courses, the one at M. I. T., was accorded the status of an independent department of engineering.

That scientific paternity was good. The electrical engineers were working in a new field for the useful applications of science. The spirit of investigation

was needed, rational reasoning instead of empiricism was essential for expanding the field, and scientifically established units of measurement were of incomparable moment. Each of these important features came to electrical engineering in admirable degree through its paternity and we are deeply indebted to the old-time physicists for the result. However, by 1891 the field was fast expanding its economic service and it was time to establish its rating as engineering rather than as a special branch of physics.

In 1891 the route for the development of electrical engineering was still uncertain. Also, textbooks in the particular field were mostly *non-est*, or inadequate. It was therefore something of an undertaking to formulate an educational policy and a suitable curriculum, develop text material, begin accumulating laboratory equipment for a period which turned out to exceed fifteen years, and gradually gather together a staff (mostly of my own students) possessing live appreciation of the characteristics of a growing branch of engineering. Fortunately, the University authorities looked with a favorable eye on members of our electrical engineering staff developing professional practice as consultants in the field. That enabled us to keep closely in touch with engineering practice and industry, at a time when industry was still inclined to look suspiciously on the views of college professors of engineering, as perhaps being "too theoretical" for the needs of the world of reality. Activity in the world of engineering practice is no longer so important for electrical engineering professors, since the industries have come to approve close cooperation with the engineering schools, and important men in industry seem to be as proud to cooperate with us as we are to cooperate with them. Associated with this change, however, is a need for revision of salaries to a more favorable scale in many engineering schools, in order that appropriate men may be commanded. Perhaps closer cooperation with industry by an increased proportion of physics professors is now needed. Many professors of chemistry and of biology, and even of mathematics, seem to relish a reasonably close intimacy with the data of industry.

Affairs at the University of Wisconsin developed very well in electrical engineering. Competent students came in increasing numbers (from Wisconsin and other states), the University become recognized as a suitable center at which to study the branch, and undergraduate work leading to its bachelor's degrees naturally served as a structure which was extended into graduate work. So, in time, we had in our student body a proportion of graduate students who received master's and doctor's degrees, while people at large were still urging that no graduate study in engineering was worth while except in Europe, and industry still cast doubt on the desirability of students spending time for graduate study instead of at once (after receiving their bachelor's degrees) going into engineering employment. Our ideals of electrical engineering led to emphasis on the experimental and mathematical-physics aspects of electricity and magnetism, mechanics, thermodynamics and hydraulics. Our classrooms were discussion grounds for the scientific and applied aspects of the topics. Our laboratories became localities for investigation and the development of ideas.

We knew that many acts that are performed in the name of education are as meaningless as the act of a fisherman casting his net in waters where it is sure

that there are no fish. We also were convinced that electrical engineering education must be creatively progressive if it is to fulfill the purpose of its establishment. We therefore asked ourselves many pertinent, and sometimes embarrassing, questions regarding our project, its aims and the processes of carrying on. We were not always able at once to give satisfactory answers to our own questions; but in any event we proved that the old-time idea of college teachers of the former generation, that the majority of students are "dubs," is wrong. Our students became independent-minded, intelligent thinkers. They also developed a sense of cooperation and a sense of the relative fitness of things. We of the staff developed a responsibility for cooperation with our students, and with other departments of the University which could aid us in our affairs and which perhaps we could aid in return. We also cooperated by exchange of ideas with industry wherever industry would respond.

Many sterling professors with a few students in scientific branches had made similar accomplishments, but here we were testing the possibilities with a staff of some numbers and an enlarging group of students, which increased the difficulties. Engineering techniques in a scientific world are transmissible through language because each step has been observed and described, but arousing concretely visualizing imagination, self-reliance, ambition and the joy of accomplishment in students is another matter. The characteristics of mental reactions are as unravelled, as yet, as the mysteries of time and space. Moreover, the tempering of the mind developed by the students' own efforts proved to be an important subject for supervision. The tool which is too hard is brittle and may fail to perform its expected service, while that which is too soft is bound to fail upon the imposition of any seriously exacting task. In illustration of this let us think of an interstudent argument. A capable argument leaves something worth while sticking in mind, while too refined an argument is easily shattered and leaves little behind except débris. A soft and lazy argument commonly is ineffective because of lack of penetration.

To accomplish our ends we found it necessary to specialize the staff more fully than had been usual in electrical engineering education, thus following the footsteps of older branches of learning in science and letters. We also found it desirable *inter alia* to add more weight to the applications of chemistry than had been usual in electrical engineering, and in 1898 set up a curriculum in electrochemistry leading to an engineering bachelor's degree alongside of our major curriculum in electrical engineering. I believe this was the first formal curriculum in applied electrochemistry in the country. It developed under the leadership of one of my students, Chas. F. Burgess, now well known for his "Burgess Batteries." The next such course, I think, was the one set up by the Physics Department at M. I. T. in 1901.

We proved to the full that competent teachers of engineering, dealing (as they should be) with science and its applications which are always expanding, find themselves up to the elbows in enquiry and adventure and we were carrying on with enthusiastic realization of the interest in the work. In the midst of this, the Executive Committee of M. I. T. asked me in the summer of 1906 to take the post of head of the Department of Electrical Engineering in their institution.

This was an interesting opportunity and in February, 1907, I transferred to the new post, and again met the old-time pessimism regarding the possibility of expecting reasonable accomplishment from the general proportion of students. This pessimistic attitude of the electrical engineering staff at M. I. T. apparently was disturbing to the alumni; and the fact that I was well known as an active consulting engineer, as well as a professor, which gave intimacy with conditions for the student after graduation as well as during his college periods, seems to have weighed in my selection for the particular post.

The electrical engineering course of M. I. T. I understand to be the oldest formal course in the subject in the world. It was established in 1882 at the suggestion of Professor Chas. R. Cross, then head of the Department of Physics at M. I. T. It was announced in a circular of August, 1882, as an activity under the direction of the Physics Department. It remained under that direction until 1902, gaining great distinction in the meantime. The golden jubilee of conferring degrees on students who pursued this course will be celebrated in June, 1935.

The course was set off from the Physics Department, and the Department of Electrical Engineering established, in 1902. The brilliant Louis Duncan, now deceased, was head of the department for two years, and then was succeeded by Harry E. Clifford, now dean of the Engineering School of Harvard University, as acting head. A great spur to individual intellectual activity among students during the latter eighteen-eighties and through the eighteen-nineties had arisen from observing the extraordinary growth-process of electrical engineering from a germ into an influential industry during that period. Electrical engineering was still growing extraordinarily in the nineteen-hundreds, but it was more in the way of expansion of similars and of consolidating the position than as revolutionary changes such as had characterized the two preceding decades. Later, a farther great expansion of the field arose as a consequence of additional discoveries in physics, the influence of which is still spreading unceasingly.

It probably was easy for department affairs under the conditions of the nineteen-hundreds to become pyramided and conventional. In any event, there was considerable dissatisfaction among alumni regarding recent conditions of the department and a full review of the situation was in order. Educational habits frequently are the result of influences that produce conventionality as wooden and superficial as that making the one-time distinction between the Western peoples and the peoples of the Near East to be stated as "those who wear the hat and those who wear the beard."

A revision of the curriculum to secure greater depth and vitality was promptly made, the method developed at Wisconsin for emphasizing desirability of graduate work (of which there had been substantially none in electrical engineering at M. I. T.) and carrying the higher investigatory methods of science into the undergraduate work was introduced; the doctrine was ceaselessly preached that students who successfully met the entrance tests of the Institute had a right to be thought of and treated as young men with ambitions and also as individuals whose intelligences should be cultivated by planning work with them to be carried

out with counsel and advice from members of the staff; needed additions were made to staff; and the definite idea of research as a part of undergraduate processes of education was introduced. The department was thus launched on a career of progression which it still maintains. It now attracts students from all parts of the world. Its number of graduate students is substantially like the number of senior students and the latter is substantially like the number of junior students. About one-half of the number of graduate students have secured the bachelor's degree in electrical engineering at M. I. T. and the other half come from elsewhere.

The M. I. T. Executive Committee in 1907 were proponents of greater attention to research in the Institute. This, however, was in mind as mostly pertaining to the work of the staff and the development of graduate study. It appeared to them as plowing virgin ground to consider research as an important feature of all engineering education (or, indeed, of education in all scientific branches), whether of graduate students or undergraduate students, but they courageously supported the project planned in that purpose. The difficulty of making such a project successful is not with the students when they are properly informed. They grasp at the opportunity for vitally touching the living structure of science and economics which is engineering, or of science alone if engineering is not concerned. The difficulty is to instill into the *members of staff* ideas of the conjoint influence of research and pedagogy, so that they will carry on with full effectiveness. This is a problem of imagination and of effective visualization of processes and desired results, to be developed by each member of the staff by means of constant effort. Unless the mental development of each student is felt by himself, as a consequence of his own efforts, the plan cannot be a success because each as yet immature individual among the undergraduate students will become discouraged with the results of his own personal efforts carried on under supervision and will begin a clamor to be "taught" instead of being expected to study for himself. Such clamor is a reversion to the old-time American idea of a college with "pedagogues" for its faculty. However, the students of science or of its applications in medicine or engineering who is permitted to pin his faith on the sleeve of his alma mater instead of being expected to pin it on himself is likely to feel ultimately that he was misdirected in his education.

The importance of using exacting processes in the selection of staff members is thus brought into bold relief. Some discussion of the selection and administration of a suitable teaching staff for engineering branches is contained in my addresses to the Society for the Promotion of Engineering Education in June, 1931, and in June, 1933.[1] It is sufficient to say here that a teacher of engineering to satisfy the criteria must make for himself so fully a mastery in some particular subdivision of engineering that he becomes an active investigator on account of the very nature of engineering and the difficulties to be overcome in its mastery. If such a man associates personal industry and foresight with his qualities, he will never fail to stir to authentic accomplishment in their studies all those students who are appropriate to follow him. Students who are alive mentally possess the quality of alert and serviceable curiosity, and it

is my opinion that only that kind should attempt to follow careers in science with expectation of being rewarded through making distinguished achievements.

Here we have the inspiring effect of successful work which carries the students successfully onward. It is the antithesis of that continual frustration felt by a student when under an inadequate instructor which results in the silting up of his original reservoirs of thought. Such frustration ultimately extinguishes any anticipations of joy from achievement and thus turns dormant or destroys the germs of ambition. It is so easy to side-slip into vagueness of thought and expression that this pitfall must be sedulously guarded against in the staff. For achievements in the engineering world (and probably likewise in other scientific branches) one must be a hard-boiled realist with whom only perfection of result is finally satisfactory; and, for a student who may have gathered some inkling of this, "the force of mere words is soon spent," as he soon perceives that the saying of high-sounding words and the doing of things either intellectually or physically are two very different occupations. Moreover, words and reality do not always move in the same sphere and teachers and students are both under some stress to maintain their definitions of words so that they respond to reality, in order that sound thinking may prevail. Clear definitions responding exactly with reality are a test of sound thinking.

The Yogin of India is supposed to "acquire credit" with his ugly deities by sitting with blank mind through life, but mental activity and originality are needful for any one who expects to gain favor from the fascinating gods of science and engineering. In order that we may have the right kind of staff members in the engineering departments, experience has proved that we must make them for ourselves by so arranging that suitable older men shall supervise, counsel and aid promising younger men while in the process of forming their pedagogical habits. The pursuit of usual formal courses in education rather diverts than concentrates the mental activities that are needed. Reading certain books by great teachers or books which describe their processes is helpful to the neophytes' effective development; but it must not be forgotten at any time, that mastery in the individual's chosen subdivision of engineering (or other branch of higher learning) is a primary matter for which he must struggle. We cannot accomplish high results in higher science education if the life-spirit of the professors is shrunk to a commonplace and lacks the romance that is a part of essential mastery.

When thus making research a part of the educational process it is necessary to be sure that we know what we mean by the word research. A definition which I long since formulated for my own guidance is appropriate to repeat here. It is, "Research is the process of detecting and identifying facts and discovering their relationships." This is a process which is essential in any highly distinguished practice in engineering and medicine and one which should be woven into the fabric of all science education at as early a period as student maturity will permit. It must not be assumed that the research results of any individual student at any time will be of value beyond the man's intellectual maturity at that time. Research problems will be more exacting for seniors in college than for juniors, and valuable contributions (except to their own intelligences) will

not result from either group, except infrequently; but research results from men approaching the doctorate may be of distinction, and research of staff members should always be of distinction or the influence of the staff as a guide for students and in service to the world of knowledge is lost.

Theoretical and experimental science, medicine and engineering are all fields of creative endeavor for their important followers, and a feature of creative endeavor is to formulate and work out problems which in unsolved state stick into and rasp the intelligence like burrs under a horse's saddle. It is not that we do or should expect many of our students to become employees of organized research laboratories; but it is needful for them resourcefully to use the research technique in whatever branch of science, medicine or engineering their life leads them into. By the time they are through their sophomore years, the science students in the American universities are the full equals in ambition and intellectual level of matriculates of European universities and those who can profit by it should be given wide freedom in planning and carrying on their work. Under such circumstances it is a failure in judgment to hesitate to place on such young men the responsibility of individually carrying on research as a feature of their college education. Anyone responsible for planning and directing such a project of education within the fields of science, in the manner thus outlined, must possess and exercise the same important intellectual qualities that equally signalize the scientific research man, the originator and planner of engineering works and the medical diagnostician. To those qualities, also, he needs to have added a certain aspect of human sympathy that arises from keenly applied powers of observation and intuitive understanding secured out of imagination.

Here I will introduce a few words regarding the proportion of engineering students who may be justified in entering upon graduate study. I imagine that like proportions may apply with equal validity to groups of students pursuing other scientific branches. I have heretofore referred to the degrees of Bachelor, Master and Doctor. In keeping with the majority of American precedents, I think of these respectively to be secured as the consequence of intelligently pursuing a four-year college curriculum or its equivalent, then pursuing at least an additional year of more advanced and concentrated study, and finally pursuing still farther advanced study of concentrated character associated with extensive planned research on a chosen topic during the most part of at least one of the years.

At the University of Wisconsin and M. I. T. over 3,000 degrees have been secured by students working in programs for which I have been primarily answerable as the responsible chief.* The number of individual students is fewer because several hundred have secured two degrees in success from such programs, but the experience has been sufficiently wide to give weight to my observations. Of course, human beings who possess a reasonable degree of brain activity are

* Including the graduates of 1935 year, the total number of degrees in electrical engineering that have been conferred by M. I. T. are bachelors' (S.B. in Elect. Eng.) 2,592, masters' (S.M. in Elect. Eng.) 762, and doctors' (D.Sc. with major in Elect. Eng.) 32. About three-quarters of the bachelors' degrees, all except two of the masters' degrees and all of the doctors' degrees have been conferred since the methods which we worked out at Wisconsin were brought to M. I. T. Both the masters' and doctors' work have become very important parts of the concern of the electrical engineering department, but at the same time great emphasis is laid on maintaining the high standard of the department's bachelors' work.

not reducible to a common denominator. That is one among several cogent reasons for practices to which I will refer in later paragraphs, while I deal at this point with a particular feature of engineering. Youthful entry into the active affairs of industry is well known to be advantageous for young engineers who do not plan to become specialists. Therefore, the additional time and expense required for graduate work may perhaps only bring returns to students who secure the bachelor's degree rather young and who are of particular ability. The age is not of so great importance if the particular individual plans to become a specialist, such as a designer in some branch of engineering, an employee in an organized research laboratory, or a professor of some chosen branch, but prime ability is notably important.

It has seemed to me that (in round numbers) one-quarter of the students who have secured bachelor's degrees under my jurisdiction might expect to profit for life from carrying on suitable graduate work to a master's degree. By "suitable graduate work" I mean such as may be comprehended within the terms of the introductory part of my address for the Board of Investigation and Coordination of the Society for the Promotion of Engineering Education at Madison, Wisconsin, in July, 1933.[2] The same address discusses work for the doctor's degree in the part relating to staff. It has seemed to me that not more than perhaps 20 percent of those appropriate to profit from some graduate work should be encouraged to proceed to the doctorate. However, these stated approximate proportions may change with changing conditions of life as they affect the engineering industries, such as manufacturing, transportation, intercommunication of intelligence, electric power generation, electric transmission and distribution of power, and their many related activities to which engineers apply their minds. As already stated, I think that similar proportions of the student body in other scientific branches may belong in "suitable graduate work." There is an old saying that "circumstances alter cases" which, like most old sayings, contains a suggestive proportion of noble truth which is not always remembered by amateur prophets. Certainly circumstances of living have changed tremendously during the span of a generation; but the established older folk fail to appreciate in what manner the circumstances surrounding present youth have changed compared with the circumstances surrounding their own youth. They therefore fail to appreciate the reasons for the restlessness of youth and the justice of youth's claim that the conclusions applied to its case must be adapted to existing conditions.

In pursuing education it is necessary to first amass pertinent facts and then to cultivate reasoning powers. Of course, the two processes overlap and should be more or less intertwined, but early education puts emphasis on the first and more mature education transfers the emphasis to the second. Some people never get to the latter and others fail to progress even far enough to gain ability to scrutinize alleged facts and distinguish facts from fancies. Inadequate results of education are all around us. The words of clear thinkers (unless they are given the emphasis of constant reiteration) have as little effect in times of emotional stress as a few drops of clear water falling into a muddy river. Processes of education therefore must be scrutinized and tested for effectiveness before

being adopted for a specific purpose and level. And this leads us to certain details of procedure.

In 1907, Dean Langdell's introduction of what was called the "case system" into the process of teaching the students in the Harvard Law School was still being ardently discussed and the case for and against its use in other law schools was being argued. Some of the friends of M. I. T. had been convinced of the importance of the "case system" in education for the law and thought that we ought to try it in association with the revised processes of the electrical engineering department. For instance, Frederick P. Fish, leading member of the American patent bar and warm friend of M. I. T., urged the point. We had to face the issue squarely and make a convincing decision.

Careful thought resolved the matter rather easily. There are marked differences between the problems arising in interpreting the law and problems arising in engineering. There also are marked differences between the Pedagogical methods of the law schools and the engineering schools as previously existing. Interpretations by the courts of the meaning of legal scriptures (constitutions, statutes and other papers) and the application of such interpretations to new cases is of primary moment in the law, for each court's decision is persuasive and a highest court's decision is controlling. The individual study by students of cases previously dealt with by the courts, with practice in making application to farther cases (*i.e.*, the case system) seems under the circumstances somewhat analogous to, and for the law student as necessary as, laboratory work in the electrical engineering laboratories for the electrical engineering students. The High Court in the engineering case is Nature who provides us with her forces, her deposited materials, and with growing flora and fauna. Facts of nature, their interrelations which we often call natural laws, and the universal relations that connote human society are the three great features of a great education where science constitutes the spinal chord and vertebræ.

Careful gathering of facts from which to construct premises, examination of each one of the premises to test its completeness and therefore its soundness, weighting the premises according to their relative soundness, observing the interrelations of the premises, and thereupon carrying on to conclusions that result in an embodiment (whether it be in words or as a design or a structure) is our needed process in science. Thus, contrary to the situation faced in the law, precedent is of less importance than direct action. Often in engineering and medical problems, precedent and accompanying empiricism become important because rational science does not cover the entire situation; but even in such cases the engineer and physician endeavor to carry through in such a way as to improve on (thereby modifying the weight of) precedent. The "case system" as such, that is, as known to the law school, therefore, is not appropriate to us in its usual formula. Moreover, while in general there is a relentless continuity in the ways of Nature, yet at times she is quite disdainful of precedent and we must be on our guard.

Solving problems that relate to applications of physical science for engineering students and to diagnosis for medical students, associated with mind-stirring investigation in laboratories, comprise in science the analogy of the law stu-

dents' "case system" and it seems to me that we are fortunate in possessing such soul-stimulating instrumentalities.

However, we have not rested content with the adoption of instrumentalities and procedures. We also have assured their proper use in stimulating every student to his best intellectual development. The formalist or systematist in methods commonly forgets this, and he also forgets that the art of contrast is an important implement in the hands of a teacher. I think that it was partly forgetful lapse of visualization regarding the individuality of students that led to the cult for small colleges which flowered in this country a few years ago. Experience guided by sound imagination proves that the large college or university has advantages over the smaller organization. For example, a large staff comprising able men, each with a mastery in his own field of learning, permits a wider choice of mentors from among which students may select their individual guides. This reasoning is equally applicable for large departments compared with small departments in particular branches of learning. The reasoning is only sound, however, when the usually asserted wholesaling principle, "when dealing with increasing numbers of units the cost per unit decreases," is firmly put to rout. My experience is that increasing numbers of students in the department must be paralleled by a proportionally increasing budget if a topmost excellence of results is to be maintained.

Then we can subdivide our large classes into sections of moderate size and of relatively homogeneous intellectual maturity; we can encourage every student to take a lively interest in his own intellectual development by happy use of conferences, the library, and the laboratories; we can maintain intimacy between students and staff just as well as in a small department; and we can introduce perhaps more effectually the stimulating effects of comprehensive examinations. Intimate cooperation with industry also perhaps is more readily maintained.

I have put into effect and maintained all of these things in a large and growing department and proved them to be desirable at a time when it was usual to deny the serviceability of such processes in education for electrical engineers, with which field I am particularly associated. Fruits of the processes (in the form of educated men) are now found in a large number of engineering schools of the country and in some of foreign lands, besides being widely spread in industry. The processes have proved to be increasingly effective as numbers of students and staff in the department have increased. The old-time type of teacher who is ready to teach in a wide range of subjects learned from the textbooks, but who is without depth of mastery, will not do in such situations. The traditional idea that a fine teacher is made by his love of young men is wrong. This came from the same period as the thought that those who had proved themselves incompetent in other occupations would be competent to teach, which also is wrong. Nowadays we consider competent to teach in the higher scientific branches only those who would be highly competent in any other occupation that commanded their intellectual and physical interest. Hence, mastery of a subject and the spirit of research have come into their own as part of the tests of competency of a teacher in higher branches of science education.

The teachers in the new ideal must be masters in their individual branches of learning, cooperating with their fellows to prevent objectionable gaps in covering the total field, enthusiastic in research to add to their own knowledge and usefulness, generous-minded and above the artisanship taint of withholding full information for fear others may profit and become great enough to be competitors, so in love with their subjects that it is a joy to expound the topics to others in an interesting way. To these qualities we try to add the humanly sympathetic imagination referred to in a previous paragraph. Those are the specifications which I give to you. When put into effect they do not fail, and the entwining of pedagogy and research in scientific education becomes a glorious fact which reacts to the advantage alike of students' mental growth, enlargement of staff's creative contributions, and spread of institution's reputation jointly for educational effectiveness and additions to knowledge in the fields of science. It is easy to see the reason. It is because interest in the occupation is aroused by drafts on the intelligence. The process makes contributions to both wisdom and character. A proportion of what now is reputed, within the precincts of our universities, to be "productive scholarship" is painstaking and industrious, but as far as adding new ideas to the world of thought or improvement on old ideas is concerned, it may be bare of productiveness. Moreover, it sometimes is as devoid of sound basis as a frog is of feathers. Uninspired labor looks downward, forward and around about, but not upward. Creativeness, on the contrary, stands with head high and chin up.

Human intolerance toward the unaccustomed is remarkable,—it is difficult to get into a well-populated birdhouse without setting the birds to chattering—and it is one of the duties of higher education, and particularly of engineering education, to substitute for this repugnance toward the unaccustomed an interest in producing new and original projects. There should be associated therewith an appropriate spirit of impartially examining and testing new and original ideas for the purpose of disclosing and developing the best that is in them. A responsibility rests on us for maintaining the pioneer spirit in those who are our students. Those tenacious qualities which were powerful for conquering a continent with axe and gun may now become occupied in providing (for the social organization) wiser utilization of the advantages which are offered by preventive medicine, improved sanitation, improved transportation, quick communication of intelligence, convenient power supply, improved methods of artificial illumination, and reduced physical labor resulting from the use of machines. As an aid to a still wider tolerance and a still fuller appreciation of the benefits of creative effort, we now have a practice in electrical engineering of exchanging each year an assistant professor of M. I. T. for a corresponding faculty member in another engineering school.

We live in the spring of time. The world has not yet come to the age of stable and generous maturity. It is still in the fighting, hoodlum stage of youth which loves pioneering. This nation would be the gainer if every American boy during his life from twelve to sixteen years of age should read Tom Sawyer and Huckleberry Finn, in some garret or shed, with imagination free from supervision by a cautious relative fearful of the lodgment of a mental germ of

fractious character. We might then again have a pioneer-minded population. It would be pioneer in a different sense from the life of preceding generations in this country who made physical conquest of prairies, mountains, forests and mines. That conquest has been mostly completed, but the prime sources of wealth for the population are still limited to the forces, materials and growths of the earth on its surface, in its bowels and of the waters thereof and of the atmosphere above the earth, plus the influence of modifications caused by human effort. Therefore, the national area now being fully held, pioneering of our day is in the art of making science more serviceable, and social development honest and sound. This has possibilities of fascination equalling the old-time pioneering, and it can likewise give compensation in the way of a satisfactory living for each pioneer and his family. This kind of pioneering, like the pioneering of old, to be safe and successful requires control by the hard-thinking and logical-minded of the population. It cannot be accomplished by sentimentalists, cloudy thinkers, and self-seekers with so many of whom we are troubled today. Had we such pioneering, we would again give full recognition to the great qualities of our form of government with its freedoms and its moderate restraints —a great legacy established by pioneer statesmen the short space of a century and a half ago, with a wisdom unexcelled in affairs of government. We of scientific education are seriously challenged to do straight thinking and to assume some active part in affairs, in order that major changes that result in disservice may not be brought to pass through the efforts of inadequate-thinking political theorists.

The engineers are the inheritors of a great part of the field in which science is made useful to man, and in which it may be made continually more useful. The challenge thus lies heavily upon them. For example, it is time to arouse influence against the spendthrift policy of spending hundreds of millions of dollars (which we do not have and therefore have to borrow at the expense of future generations) to establish a permanent plant which we do not want for the reason that a need does not exist and the expenditures will never provide either an economic or a social return in keeping with the sacrifice imposed on the citizen taxpayers. The exigent need is to pick out and preserve the socially serviceable government projects, like eliminating grade crossings of trunk line highways with railroads, and to endeavor to destroy the inappropriate projects such as various electric power plans. These are but illustrations in a wilderness of shocking financial schemes and of extravagant spending. If the influences of jealousies, superstitions and ignorance could be obliterated from the minds of the electorate, how easy it would be to produce the reform. As it is, fulfilling the need is indeed difficult to accomplish.

The purpose of Sigma Xi is to promote research. That sounds inspiring, but what does it mean? Not being satisfied with the indefinite definitions usually assigned to the much-used word "research," I formulated a definition for myself. It says (as already stated) that research in the sense meant by Sigma Xi is a process, and specifically the process of detecting and identifying facts and discovering their interrelationships. I think this definition strips the word of much of its cant and presents it in its proper dress. It puts the emphasis on dis-

covery of relationships, which is where the emphasis belongs. I assume that there are mighty few *ultimate facts*. Regarding this, you may agree with me or not, as you please; but I challenge anyone to name one *ultimate* fact which we know. If a man thinks he has gained possession of one, let him examine it carefully, and he probably will find that his ultimate fact has slumped into a mere knowledge of relations.

Most people, for example, think of the syllogism as an ultimate fact in reasoning. I was so taught in college. However, one long-past day I chanced to read F. H. Bradley's book on "Principles of Logic" and was led through a cogent proof that the syllogism is not a necessity for exact reasoning but is only a convenient and habitual expedient. Thus the ultimateness of my one ultimate fact in the science of logic was destroyed. However, I continue to use the syllogism as an instrument, and do so with content, if not always with convincing effect.

In farther illustration I will take the discovery of electromagnetic induction by Michael Faraday. This is one of the most magnificent among the discoveries which have been made as the result of careful reasoning plus experimentation. But this did not give us a single ultimate fact. It gave us knowledge of certain very important and beautiful relationships and pointed to many associated relationships. Nobody has yet identified the ultimate facts which underlie these phenomena, although physicists ever since have been exerting themselves at full power to that end. They may be making progress. Certainly they are discovering many additional important and interesting relationships, but the ultimate fact or facts still elude them. It is easier to storm and break through all the trenches, breastworks, barbed wire and walls surrounding a well-fortified and provisioned citadel than it is to take the citadel itself. Any *ultimate* fact lies in such a citadel. The ultimate fact or facts of electromagnetic induction still rest secure in their citadel. The simple and homogeneous atom did not prove to be an ultimate fact, and now the electron is going the same way.

In the meantime, physicians, engineers and other applied scientists proceed to put the discovered relations of electromagnetic induction and a host of other relations to use in the production of means which contribute to comfort and convenience of ourselves and our fellow-human beings, constantly utilizing the processes of research for finding the paths to traverse. Unless we run out of resourceful originality and the spirit of enquiry, we will go on doing this in fuller and fuller degree until we have exhausted all the possibilities of those relationships that are already known or which are discovered in the course of our work, and then we will have to stop and wait (unless we join our forces in the attack) for the research physicists, chemists and other professional research men to penetrate toward some additional citadel; and then again, when this is accomplished, there will be a blaze of progress in the applications of science which serve to improve human health and comfort.

Thus it is that the cloistered scientist and the applied scientist contribute hand in hand to the physical comfort and convenience of mankind each using in his own way the process of research. When a task is smoothly accomplished with little general publicity during the procedure, people are likely to think of it as having come to pass of its own accord and they forget the foresight in planning

plus concentration in execution that few have the persistent will to encompass but which are essential elements in achieving the smoothness in accomplishment; or people may falsely cry out on the result (as when critics propose a moratorium on research in the field of science) because they have not consulted the plain evidence of the past compared with the present. I commend to young scientists in all fields the cultivation of fine qualities; discriminating analytical powers with which to conduct exploration; imagination for arousing vision of a promised land; curiosity for inciting experimentation; penetrating powers of visualization for observing results of analysis or experiments; synthetic intelligence to formulate conclusions and derive results. Lacking the first named of these great qualities, possession of the second and third are likely to lead one into blind alleys and dangerous paths. The first and last named are the greatest of the five, but these need the support of imagination, curiosity and visualization to bring out their greatness.

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[1] Proceedings S. P. E. E., Vol. XXXIX, 1931, and Vol. XLI, 1933; *Science*, Vol. 74, August 21, 1931, and Vol. 78, October 6, 1933.
[2] Proceedings S. P. E. E., Vol. XLI, 1933.

Forestry and the CCC

(*Concluded from page 161*)

for a type of forestry not patterned solely after European practice, but a type evolved and tested through experience gained from actual practice. A real American forestry is being created! The effect of the CCC on the public mind is also of great importance to forestry practice. Never before has the treatment of forest areas been brought as strikingly before the public as it has since the inception of the CCC. Whether or not one agrees with the present policies, an interest in what is going on in connection with forest conservation has been aroused. It seems probable that such interest will not measurably decrease in the future, and that an advance has been made which if properly guided and directed will have an increasing influence on the attitude of the public towards forestry that will greatly affect its future.

The question of the permanence of the CCC is now an important problem of the forest conservation, both to the professional forester and to the general public. Shall the CCC be given up as a temporary relief measure, or shall it be continued as part of a national policy for taking care of the excess population and as a permanent means of improving our forest areas? The opinion of the majority of foresters, who are closely in touch with the situation, seems to indicate that the beneficial effects of the CCC on the men and on the forest justifies its continuation as a permanent social factor, with perhaps some changes that have become advisable through the light of experience gained since 1933. But no matter what may be the ultimate fate or form of the CCC, its stimulative effect on forestry practice will be felt for many years in the future. The results of the work thus far expended represent a great step forward in forest conservation which has given evidence of the fulfillment of the proposal of the President, "to accomplish constructive results in our vast Federal, State, and private forest properties."

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Smith	Gladys A. Anslow	E. C. Faust	C. L. Stearns	Elizabeth S. H
		H. B. Goodrich	Geo. Olds Cooper	
		N. H. McCoy		